(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 087 256 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
28.03.2001 Bulletin 2001/13

(51) Int. Cl.[7]: **G02F 1/225**

(21) Application number: **00307820.1**

(22) Date of filing: **11.09.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **27.09.1999 GB 9922840**

(71) Applicant: **ALCATEL**
75008 Paris (FR)

(72) Inventor: **Webb, Stephen Michael**
Sidcup, Kent DA15 9NA (GB)

(74) Representative:
Hackney, Nigel John et al
Mewburn Ellis,
York House,
23 Kingsway
London WC2B 6HP (GB)

(54) Optical modulator

(57) An optical device is disclosed for the external modulation of the output 4 of an optical radiation source. The device includes a first optical modulator 2 driven by an NRZ coded electrical data signal 3 so as to modulate the output 4 of an optical radiation source. The device also includes a second optical modulator 6 coupled to the first optical modulator 1 and driven by one or more drive signal sources 7, 8 from electrical circuit 9. The circuit 9 drives modulator 6 so as to provide an optical AND function to convert the NRZ coded optical signal output the first optical modulator 1 into an RZ coded optical signal and to simultaneously introduce a degree of phase modulation (e.g. pre-chirp) in the RZ signals modulated thereby.

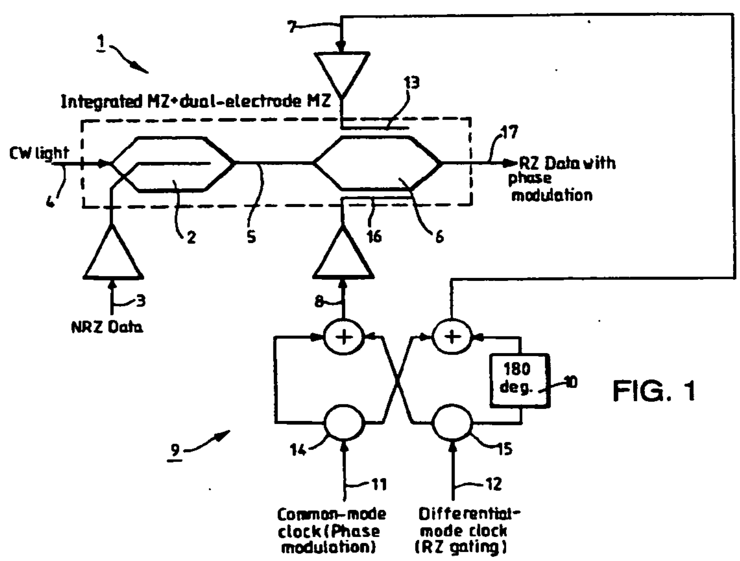

FIG. 1

EP 1 087 256 A2

Description

Background to the Invention

[0001] Optical transmission systems are generally based on one of two methods of modulation of a signal laser, either direct or external modulation. In the first of these, the bias current to the laser is modulated, turning the laser on and off. The disadvantage of this when applied to high capacity systems is that the semiconductor material dynamic behaviour introduces distortion into the laser output, known as chirp. External modulation of the continuous wave (CW) source produces a modulated output signal with significantly reduced chirp, and sources of this type are preferred for use in high capacity systems. High speed electrode-optic modulators such as Mach Zehnder devices are typically used.

[0002] One coding format for optical signals in fibre optic networks is non-return-to-zero (NRZ). In this format a coded data pulse fills the time slot corresponding to a bit period and if the next data bit has the same value no transition occurs at the end of the time slot. An example of a modulator which is designed to implement NRZ format transmission is the X2624C Mach Zehnder opto-electronic device available from Lucent. This is a dual electrode Mach Zehnder device which uses an electrical data stream and its inverse to drive respective electrodes, thereby gating (modulating) a CW source to provide NRZ optical data. By altering the two drive levels on the respective electrodes it is possible to affect a degree of pre-chirp (positive or negative) to compensate for non-linear transmission effects.

[0003] An alternative to NRZ coding is to use a return-to-zero (RZ) format. In this case, if the data in a time slot is a "1", the signal drops back to the "0" level before the end of the slot, whatever the value of the data in the next bit: a "1" is signified by the presence of a pulse located within the bit period. RZ format is more stable than NRZ coded optical signals at high bit rates, and is therefore preferred for high capacity long haul transmission systems.

[0004] One known arrangement for coding an RZ optical signal requires a first Mach Zehnder device to modulate a CW source using NRZ electrical data as the drive signal, the output of which is modulated by a second Mach Zehnder device configured as an optical AND gate to convert the NRZ optical input to an RZ optical signal at the output. The output of the second Mach Zehnder device is then coupled to a phase modulator to provide a degree of pre-chirp to compensate for non-linear transmission effects. It is not possible to provide an integrated package and therefore this solution is much more complex.

[0005] The latest 10 Gbit s^{-1} WDM optical transmission systems that are being proposed for submarine networks will provide 60 or more channels with a spacing of only 0.4nm. In future, 120 channels having a spacing of only 0.2nm will be offered. One problem with the development of high capacity systems such as these is that the footprint of the terminals required to support the systems are becoming increasingly large at a time when customers are demanding ever smaller integrated solutions to their needs. The preferred RZ coding format for high bit rate systems and the associated optical devices described above required to generate an RZ coded signal from an NRZ electrical data stream makes this difficult to achieve.

Summary of the Invention

[0006] According to a first aspect of the present invention, an optical device for the external modulation of the output of an optical source, comprises:

a first optical modulation device driven by an NRZ coded electrical data stream to modulate the output of the optical source to generate an NRZ coded optical signal; and,

a second optical modulation device coupled to the output of the first optical modulation device and driven by one or more sources to implement an optical AND function and controllable to introduce a predetermined degree of phase modulation to thereby convert the NRZ coded optical signal from the first optical modulation device to a phase modulated RZ coded optical signal for subsequent transmission.

[0007] According to a second aspect of the present invention, an optical modulator comprises a dual electrode Mach Zehnder device driven by one or more sources to implement an optical AND function and thereby convert an NRZ coded optical signal at an input to an RZ coded optical signal at an output.

[0008] Preferably, the one or more sources comprise an electrical circuit for controlling the drive of electrodes of the dual electrode Mach Zehnder device to modulate the phase of the coded optical signal and thereby introduce a predetermined degree of pre-chirp to the RZ coded optical signal at the output.

Brief Description of the Drawings

[0009] Examples of the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a first example of an optical modulator in accordance with the present invention; and,

Figure 2 shows a second example of an optical modulator in accordance with the present invention.

Detailed Description

[0010] Figure 1 shows an example of an optical modulator 1 consisting of a pair of Mach Zehnder

devices. A first Mach Zehnder device 2 is gated by an NRZ electrical data signal 3 to modulate an optical output 4 of a CW optical source (not shown) to generate an NRZ coded optical signal at an optical output 5. The NRZ coded optical signal output 5 is then coupled to the second of the two Mach Zehnder devices 6.

[0011] The second Mach Zehnder device 6 is a dual electrode device, in this example a 20 Gbit s^{-1} X2624C available from Lucent, gated by signals 7 and 8, respectively, derived from an electrical summation circuit 9 having a phase shifter 10 and fed by a common mode clock signal 11 and a differential mode clock signal 12.

[0012] As shown, one electrode 13 of the dual electrode Mach Zehnder device 6 is gated by a signal 7 derived by summing the signal 11 from a common mode clock (not shown) coupled by a first splitter 14 with a differential mode clock signal 12 coupled by a second splitter 15 via the phase shifter 10. The other electrode 16 is gated by a simple summation of signals coupled from respective splitters 14 and 15 associated with the same clock sources. Each of the clock signals in this example is assumed to be derived from the clock used to drive the data. In this manner, the dual electrode Mach Zehnder 6 may be driven in such a way as to provide intensity modulation when the electrodes are driven anti-phase or phase modulation if both electrodes are driven in-phase. By applying suitable sinusoidal drive signals to each electrode, resultant in-phase and antiphase signals can be resolved, so the device simultaneously operates as both a phase and intensity modulator. For instance if both electrodes are driven in anti-phase with similar sinusoids then no phase modulation will occur, however if one electrode is driven with double the level and the other is inactive, then there will be phase modulation in addition to amplitude modulation. If the phase and amplitude of each of the clock signals 11 and 12 are varied it is possible to change the position and magnitude of the chirp, whilst independently controlling the Mach Zehnder drive signal level.

[0013] The second Mach Zehnder device 6 is driven to provide an optical AND function to convert the NRZ coded optical signal to an RZ coded optical signal with a controllable degree of phase modulation (pre-chirp) at an optical output 17. In use, the optical output 17 represents one channel in a high capacity WDM transmission signal. The two Mach Zehnder devices can be integrated on the same wafer and are therefore extremely space efficient.

[0014] Figure 2 shows another example of an optical modulator 20 which is similar to the example shown in Figure 1, with the exception that a single fixed clock source (not shown) is used in the electrical drive circuit 21 for the dual electrode Mach Zehnder device 6.

[0015] In this example, the first electrode 13 is gated by a signal derived by passing a clock signal 22 through a first variable attenuation circuit 23 and then a first variable phase shifter circuit 24. Likewise, the second electrode 16 is gated by passing the clock signal 22 through a second variable attenuation circuit 25 and then a second variable phase shifter circuit 26. Once again, by applying suitable drive signals, the dual electrode device 6 can simultaneously operate as both a phase and intensity modulator to generate an RZ coded optical signal with a controllable degree of phase modulation (pre-chirp) at the optical output 17.

Claims

1. An optical device for the external modulation of the output of an optical source, comprising:

   a first optical modulation device driven by an NRZ coded electrical data stream to modulate the output of the optical source to generate an NRZ coded optical signal; and,
   a second optical modulation device coupled to the output of the first optical modulation device and driven by one or more sources to implement an optical AND function and controllable to introduce a predetermined degree of phase modulation to thereby convert the NRZ coded optical signal from the first optical modulation device to a phase modulated RZ coded optical signal for subsequent transmission.

2. An optical device according to claim 1, in which the first optical modulation device is a Mach Zehnder device.

3. An optical device according to claim 1 or 2, in which the second optical modulation device is a dual electrode Mach Zehnder device.

4. An optical device according to any preceding claim, in which the first optical modulation device and the second optical modulation device are integrated.

5. An optical device according to any preceding claim, in which the one or more sources comprise an electrical circuit for controlling the drive of the second optical modulation device to modulate the phase of the coded optical signal and thereby introduce a predetermined degree of pre-chirp to the RZ coded optical signal at the output.

6. An optical device according to claim 5, in which the electrical circuit comprises a first splitter and a second splitter each driven by a respective clock signal, and a first summer and a second summer, wherein the first summer outputs a signal derived by summing the respective clock signals output by the first and second splitters and the second summer outputs a signal derived by summing one clock signal with a phase shifted version of the other.

7. An optical device according to claim 6, further com-

prising a phase shifter for introducing a predetermined phase shift in one of the clock signals.

8. An optical device according to any of claims 1 to 5, in which the electrical circuit comprises a clock source coupled to a first variable attenuation circuit and a first variable phase shifter circuit connected in series and also a second variable attenuation circuit and a second variable phase shifter circuit connected in series, to thereby provide two separate drive signals for the second optical modulation device.

9. An optical modulator comprising a dual electrode Mach Zehnder device driven by one or more sources to implement an optical AND function and thereby convert an NRZ coded optical signal at an input to an RZ coded optical signal at an output.

10. A device according to claim 9, in which the one or more sources comprise an electrical circuit for controlling the drive of electrodes of the dual electrode Mach Zehnder device to modulate the phase of the coded optical signal and thereby introduce a predetermined degree of pre-chirp to the RZ coded optical signal at the output.

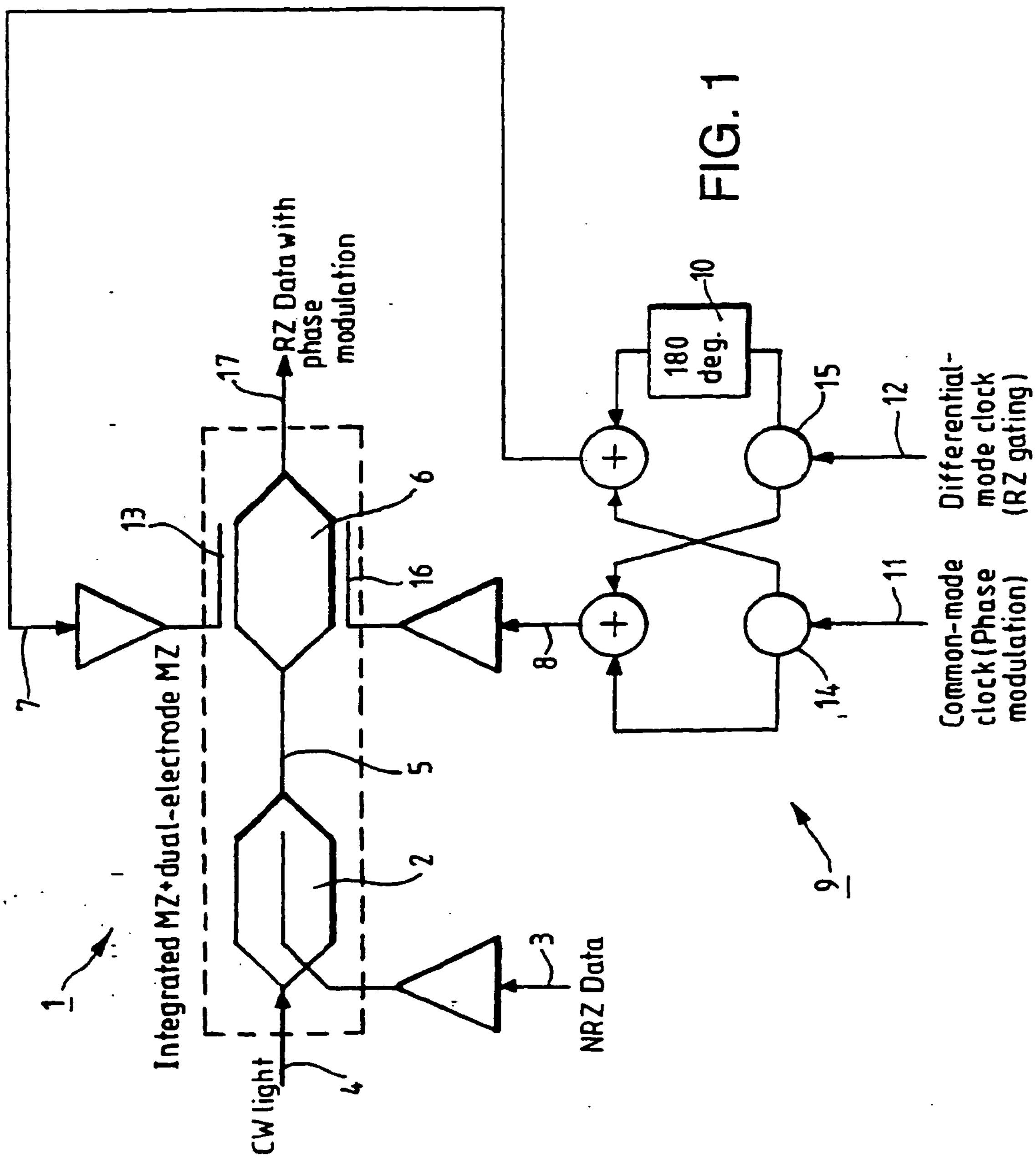
Integrated MZ+dual-electrode MZ
CW light
NRZ Data
RZ Data with phase modulation
180 deg.
Differential-mode clock (RZ gating)
Common-mode clock (Phase modulation)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

FIG. 1

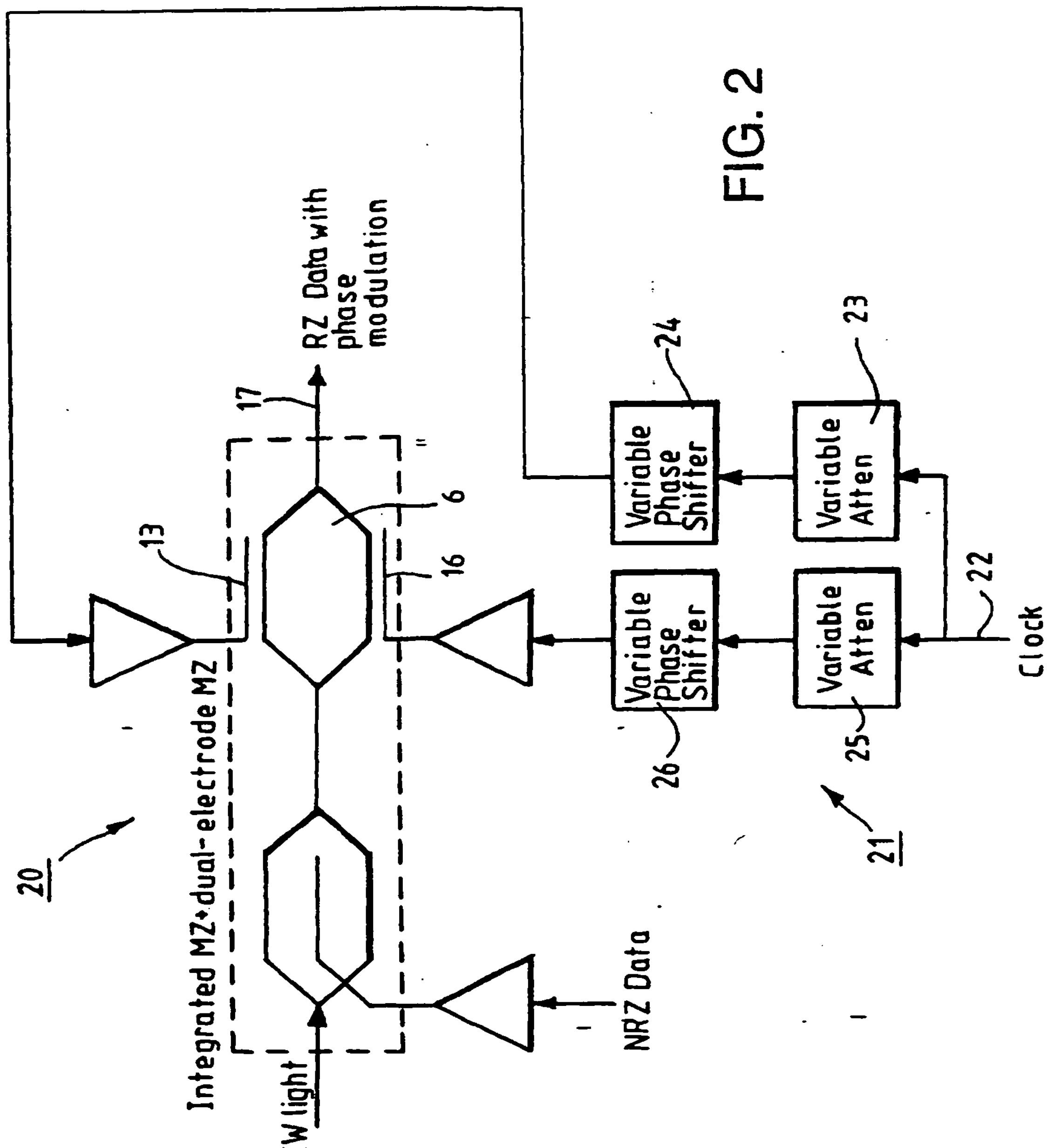
20
Integrated MZ+dual-electrode MZ
CW light
NRZ Data
13
6
16
17
RZ Data with
phase
modulation
Variable Phase Shifter
24
Variable Atten
23
Variable Phase Shifter
26
Variable Atten
25
22
Clock
21

FIG. 2

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 087 256 A3

(12) **EUROPEAN PATENT APPLICATION**

(88) Date of publication A3:
17.10.2001 Bulletin 2001/42

(51) Int Cl.7: **G02F 1/225**, H04B 10/155, G02F 1/01

(43) Date of publication A2:
28.03.2001 Bulletin 2001/13

(21) Application number: **00307820.1**

(22) Date of filing: **11.09.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **27.09.1999 GB 9922840**

(71) Applicant: **ALCATEL**
75008 Paris (FR)

(72) Inventor: **Webb, Stephen Michael**
Sidcup, Kent DA15 9NA (GB)

(74) Representative: **Hackney, Nigel John et al**
Mewburn Ellis,
York House,
23 Kingsway
London WC2B 6HP (GB)

(54) **Optical modulator**

(57) An optical device is disclosed for the external modulation of the output 4 of an optical radiation source. The device includes a first optical modulator 2 driven by an NRZ coded electrical data signal 3 so as to modulate the output 4 of an optical radiation source. The device also includes a second optical modulator 6 coupled to the first optical modulator 1 and driven by one or more drive signal sources 7, 8 from electrical circuit 9. The circuit 9 drives modulator 6 so as to provide an optical AND function to convert the NRZ coded optical signal output the first optical modulator 1 into an RZ coded optical signal and to simultaneously introduce a degree of phase modulation (e.g. pre-chirp) in the RZ signals modulated thereby.

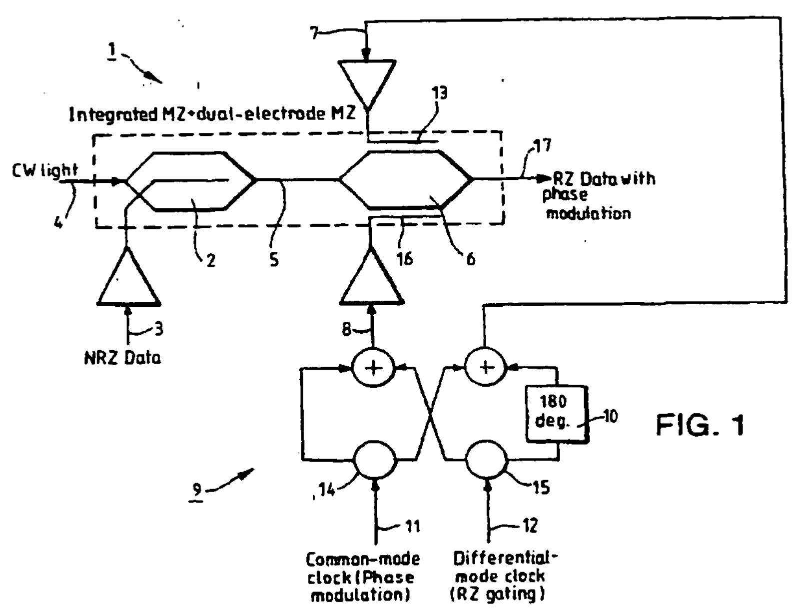

FIG. 1

EP 1 087 256 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 30 7820

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	TAGA H ET AL: "Polarisation mode dispersion tolerance of 10 Gbit/s NRZ and RZ optical signals" ELECTRONICS LETTERS, IEE STEVENAGE, GB, vol. 34, no. 22, 29 October 1998 (1998-10-29), pages 2098-2100, XP006010534 ISSN: 0013-5194 * figure 1 *	1	G02F1/225 H04B10/155 G02F1/01
A	LEE H K ET AL: "All-fibre-optic clock recovery from non-return-to-zero format data" ELECTRONICS LETTERS, IEE STEVENAGE, GB, vol. 34, no. 5, 5 March 1998 (1998-03-05), pages 478-480, XP006009414 ISSN: 0013-5194 * figure 1 *	1	
A	TAKAYAMA K ET AL: "AN ALL-OPTICAL 10-GHZ LD-BASED CLOCK REGENERATOR USING A MACH-ZEHNDER-INTERFEROMETER-TYPE NRZ-TO-RZ CONVERTER" IOOC-ECOC. EUROPEAN CONFERENCE ON OPTICAL COMMUNICATION ECOC. INTERNATIONAL CONFERENCE ON INTEGRATED OPTICS AND OPTICAL FIBRE COMMUNICATION IOOC, XX, XX, vol. 1, 1991, pages 77-80, XP000980333 * figures 1,2 *	1	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04B G02F
A	US 5 917 638 A (FRANCK THORKILD ET AL) 29 June 1999 (1999-06-29) * abstract *	9	
A	EP 0 718 990 A (AT & T CORP) 26 June 1996 (1996-06-26) * abstract; figure 1 *	9	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28 August 2001	Gill, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 30 7820

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

28-08-2001

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5917638	A	29-06-1999	NONE		
EP 0718990	A	26-06-1996	US	5625722 A	29-04-1997
			CA	2161821 A	22-06-1996
			JP	8254673 A	01-10-1996

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82